

# Evaluation of PA DO Rationale

Application to Delaware River Estuary

# Overview

- ☐ PA provided rationale for revised DO criteria in 2013
- ☐ Document includes sections on CWF, TSF, WWF, HQ
- ☐ This presentation will focus on the discussion of WWF, which would be applicable to the Delaware Estuary
  - Specifically, the 5 mg/L minimum

07/09/13

COMMONWEALTH OF PENNSYLVANIA  
DEPARTMENT OF ENVIRONMENTAL PROTECTION  
BUREAU OF POINT AND NON-POINT SOURCE MANAGEMENT

RATIONALE FOR THE DEVELOPMENT OF  
AMBIENT WATER QUALITY CRITERIA FOR

DISSOLVED OXYGEN

PROTECTION OF AQUATIC LIFE USE

*Revised 02/01/13*

Statement of Issue

Aquatic life in Pennsylvania freshwater waterbodies are currently being protected from adverse impacts associated with low dissolved oxygen by four categories of dissolved oxygen criteria (DO), which is found in PA Code Chapter 93.7 Table 3. Only slight revisions have been made to the numerical component of the dissolved oxygen aquatic life criteria since the Department of Health Sanitary Water Board adopted their Rules and Regulations in 1967. Since then, many new resources of new scientific literature and information have been made available, including EPA's review of literature that resulted in a dissolved oxygen criteria recommendation in the "Quality Criteria for Water 1986" (also known as the "Gold Book"). Based on the availability of updated scientific studies and recent concerns about the appropriateness of the current dissolved criteria, a review of the current information regarding dissolved oxygen requirements of aquatic life was undertaken.

Background

Dissolved oxygen refers to the oxygen gas that is dissolved in the water and made available to aquatic life. Oxygen gets into the water by diffusion from the surrounding air, by aeration from moving water or as a product of photosynthesis. The solubility of oxygen in water is highly dependent on the temperature of the water, but is also affected by atmospheric pressure and salinity. Dissolved oxygen fluctuates diurnally in a freshwater ecosystem due to photosynthesis and respiration. Additionally, DO fluctuates seasonally mostly due to change in water temperatures.

DO requirements for aquatic organisms were highly studied until the 1980's. As such, there are many peer-reviewed studies on the topic. The abundance of literature relating to lethal and sub-lethal effects is helpful to understanding the deleterious effects of low dissolved oxygen concentrations. Many lab experiments studying DO requirements of fish focused on determining minimum DO concentrations necessary to avoid mortality in both adult and larval stages of fishes. Other field and lab studies that examined sub-lethal effects of varying DO conditions have shown stress responses in the form of avoidance, decreased swimming performance, reduction in metabolic rate, reduced growth, and changes in behavior that may increase risk of predation. Additionally, low DO concentrations have been shown to prevent spawning, and

# Diversity of Fishes

*"The Department proposes to adopt the criteria for warmwater early life stages as the criteria for warm water fishes (WWF). Proposed criteria for WWF are 5.5 mg/l as a 7-day average and 5.0 mg/l as a minimum. Based on discussions with Pennsylvania Fish and Boat Commission, these values are appropriate since **PA warm water fisheries are so diverse** and include fish species that spawn from early spring to late summer."*

- ☐ Delaware Estuary fisheries are diverse, however not nearly as diverse as the WWFs of other basins in PA
- ☐ The Delaware Estuary represents a unique habitat type for PA (tidal freshwater river) and supports a unique fish community
- ☐ It is appropriate for DRBC to develop criteria protective of the unique fish species in the Delaware Estuary

# Diversity of Fishes

## Species cited in review of DO requirements

PA	DRBC
Green Sunfish	Shortnose Sturgeon
Bluegill	Atlantic Sturgeon
<b>American Shad</b>	<b>American Shad</b>
Smallmouth Bass	Channel Catfish
<b>Largemouth Bass</b>	<b>Largemouth Bass</b>
	White Perch
	Striped Bass
	Yellow Perch

# Smallmouth Bass

- ☐ Most of the literature review focuses on smallmouth bass
- ☐ Smallmouth bass are largely not present in the Delaware Estuary
- ☐ Largemouth bass are present in the Estuary and have been included as a sensitive species in DRBC's analysis

# American Shad

- ❑ Alosine spp. are important to the Estuary
- ❑ Difference between DRBC and PA interpretation of DO requirements
  - PA cites a value of 5.0 mg/L as necessary for juveniles
  - DRBC cites a value of 4.0 mg/L as necessary for juveniles
- ❑ Draft DRBC criteria would provide
  - $\geq 5$  mg/L DO (inst. min.) March through June
    - Includes spring spawning run and early life stage development period
  - $\geq 4.3$  mg/L DO (inst. min.) July through October
    - Includes juvenile outmigration

# American Shad – PA Rationale

## Page 9, Paragraph 3

*“Since the anadromous American shad use the Susquehanna and Delaware River basins to complete their life stages, and blueback herring and alewife (collectively river herring) utilize the Delaware River basin, criteria in these WWF river basins must also protect for these migratory Clupeid species. Stier and Crance (1985) determined that dissolved oxygen concentrations less than 5 mg/l would create a migratory block for American shad adults and juveniles. DO concentrations of 5 mg/l are required throughout the American Shad’s spawning area. A study referenced by Stier and Crance found no shad eggs in water where DO concentrations were less than 5 mg/l. Maes et al (2007) modeled migration of migratory fish species in Europe (including a species of shad) and concluded that a ‘baseline concentration of 5 mg/l considerably increases the opportunity for diadromous fish species to pass.’”*

# American Shad – PA Rationale

*"Stier and Crance (1985) determined that dissolved oxygen concentrations less than 5 mg/l would create a migratory block for American shad adults and juveniles."*

- ☐ Stier and Crance is the habitat suitability index for American Shad.
- ☐ The HSI cites Ellis 1947 in stating "**many** fish died before dissolved oxygen levels of **5.0 mg/l** were reached, and that water containing less than **5.0 mg/l** dissolved oxygen constituted a lethal barrier to the passage of shad."
- ☐ Ellis 1947 only briefly describes experimental results as follows, "**many** of these shad became helplessly incoordinate and died before the DO was reduced to **4 ppm** and **a few** even before it was reduced to **5 ppm**, any portion of the Delaware River carrying less than **5 ppm** of DO must be regarded as presenting a lethal hazard to migrating shad."
- ☐ No data are provided on the number of shad tested which makes the importance of "**a few**" vs "**many**" difficult to determine.



# American Shad – PA Rationale

*“DO concentrations of 5 mg/l are required throughout the American Shad’s spawning area. A study referenced by Stier and Crance found no shad eggs in water where DO concentrations were less than 5 mg/l.”*

- ☐ DRBC agrees with this statement.
- ☐ DRBC draft criteria would provide  $\geq 5$  mg/L DO (inst. min.) for the spring spawning run and early life stage development period (March through June).

# American Shad – PA Rationale

*“Maes et al (2007) modeled migration of migratory fish species in Europe (including a species of shad) and concluded that a ‘baseline concentration of 5 mg/l considerably increases the opportunity for diadromous fish species to pass.’”*

- ☐ Study focused on a different species, twaite shad (congeneric)
- ☐ Observational presence/absence data were modelled as a function of temperature, dissolved oxygen concentration, river flow and season
- ☐ A DO criterion of 5 mg/L was developed by determining the DO concentration associated with a 50% chance of capture of twaite shad
- ☐ Not an experimental study on the DO tolerance of shad
- ☐ DRBC would classify a value of this nature as “protective”, but not a minimum suitability threshold

# American Shad - DRBC Review

*Minimum suitable DO for juvenile American shad is 4.0 mg/L*

- ☐ Cited as DO requirement by ANSDU in “A Review of Dissolved Oxygen Requirements for Key Sensitive Species in the Delaware Estuary” (2018).
- ☐ ANSDU cited Tagatz 1961 which is an experimental study that exposed young-of-year shad to dissolved oxygen reductions
- ☐ Tagatz 1961 concludes “The present study indicates that young shad can probably survive limited exposure to dissolved oxygen between 2.0 and 4.0 ppm.”

# Seasonal Considerations

- ❑ PA uses a single set of criteria to provide year-round WWF support
- ❑ DRBC draft criteria would provide protections tailored to the specific timing and needs of Delaware estuary fish species

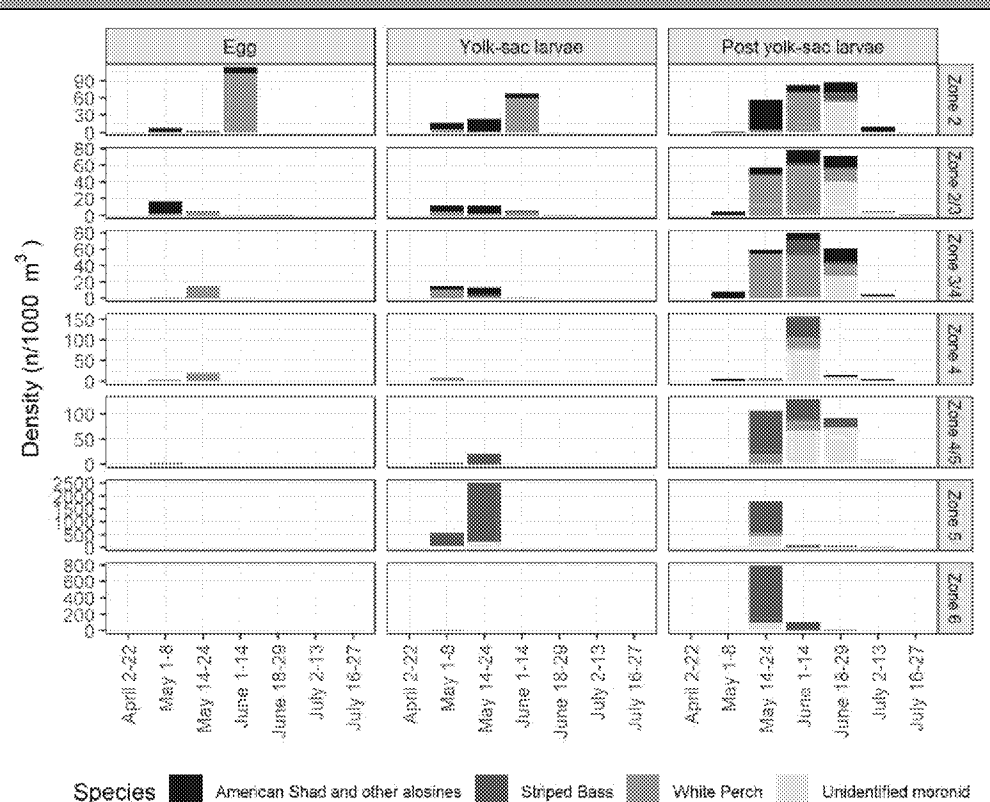
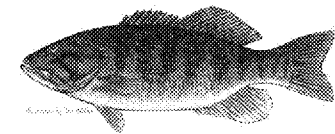


Figure 2-2: Spatial and temporal occurrence of egg and larval stages of sensitive species captured during ECSI ichthyoplankton sampling

# PA DO Criteria vs DRBC Draft DO Criteria

- ☐ Draft DRBC criteria are at times more stringent and at times less stringent than PA WWF DO criteria
- ☐ DRBC has reviewed the PA DO rationale document as it relates to DRBC draft criteria
- ☐ Key Distinctions...
  - Different Fish Communities
    - PA criteria protect a much larger group of species (all fish in PA)
    - DRBC draft criteria have been developed using best current science, and tailored to the specific needs of the unique Estuary fish community
  - Different Temporal Applications
    - PA applies a single DO criteria year-round to protect aquatic life in all seasons
    - Seasonal considerations in DRBC criteria provide:
      - Equal or better protections during the critical spawning season
      - Less stringent criteria during the summer growth season

*Smallmouth Bass*



*Atlantic Sturgeon*



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